Employed Hardware Computing for Localization Based on ZigBee via SOPC

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***Abstract*—This paper aim at the wireless sensor network indoor localization realized, build up the localization experiment and Verification analyze RSSI at feasibility and efficiency. The experiment purpose is found out the user accurate location indoor via RSSI computing. In order to real-time localization and reach the light, portable and lower consume energy, we employed SOPC development platform to design the hardware parts of WSN and RF chip control software based on ZigBee wireless communication technologies. In final, we constructed the signals strength diagrams via system measurement equations and acquired states. By way of RSSI-based and location relation model, we adapted the system various variable and weight for computing more precise localization result.**

***Keywords*—localization, wireless sensors network, ZigBee, RSSI-based, SOPC**

1. INTRODUCTION

Localization in wireless sensor networks gets more and more important, because many applications need to locate the source of incoming measurements as precise as possible. One of the main advantages of the on-chip location engine is that the algorithm is decentralized, allowing location calculations to be performed at each node. Performing location calculations at the node level reduces network traffic and communication delays otherwise present in a centralized computation approach since only the calculated position is transferred, not the data used to perform the calculation.

Many Indoor localization method required to use many transmit and receiver devices for found out the location of user. Therefore the deployment of larger amount nodes is a very important in environment. In complete indoor localizations system, the access point (AP) setting is key point. We employed SOPC based on embedded system to design heavy AP nodes for increasing the expand ability and decreasing the design cost in basic components. The location engine is a digital hardware block that enables wireless nodes to locally determine their own two-dimensional position coordinates quickly and efficiently in an IEEE 802.15.4 or ZigBee network. This is accomplished by running a statistical maximum likelihood location estimation algorithm on the received signal values from a handful of reference nodes or other dynamic neighbor nodes with the same engine.

Localization can be the driving force for wireless sensor networks in applications related to patient monitoring, asset tracking, inventory control, security, location-sensitive service and billing, warehousing, and manufacturing logistics. Node or sensor location information also can be useful for routing and scaling wireless networks. For example, wireless nodes may obtain location information using an existing system such as GPS. However, GPS-based systems may be too expensive or excessively power-intensive and complex for simple, low-cost, large-scale network applications. Besides, while localization in outdoor environments usually can be performed efficiently and accurately using GPS, this does not always hold true indoors. In many wireless sensors network applications, location-aware networks' attractiveness depends on low-cost sensor devices with low-power autonomous operation for long equipment lifetime. With ZigBee sensor networks' anticipated widespread presence and versatility, local positioning has the potential to become one of the most exciting features of these wireless systems.

A good localization algorithm should calculate a position as fast as possible and should be resistant to environmental influences as well as imprecise distances. The paper at hand is divided into the followings sections. The second section discusses the theoretical background and related literatures, the next we indicated the practical realization of measuring the RSSI (receive signal strength indication) and LQI (link quality indication) in Zigbee devices.

In next section, the derivation and implementation of SOC integrates functions for location computations are described. Our experimental results, we present in the final section followed by the conclusion which closes this paper.

2. RELATED LITERATURES

Ralf Grossmann proposed Weighted Centroid Localization (WCL) provides a fast and easy algorithm to locate devices in wireless sensor networks.**[1]** Kannan Srinivasan presented empirical measurements of the packet delivery performance of the Telos and MicaZ sensor platforms. At a high level, their behavior is similar to that of earlier platforms.**[2]** In the location tracking, the Konrad Lorincz and Matt Welsh indicated the "MoteTrack: A Robust, Decentralized Approach to RF-Based Location Tracking " for computing location method.**[3]** The Paramvir Bahl proposed another method that RADAR: an in-building RF-based user location and tracking system.**[4]** The Jan Blumenthal also employed the Low Complexity schemed to calculate the sensor nodes position estimation.**[5]** From the above literatures, the study tries to design a computing location engine by the hardware. Although these above literatures proposed some approaches to improve the location and tracking calculation, the big drawback are that the computing procedure is very hard and complexity in geometry search and calculate.

In this paper, we showed the innovative localization engines manner to compute the complexity WSN location algorithms by FPGA. This study employed the RSSI and LQI computing engines to solve location and tracking in Zigbee devices by on-chip.

3. System Framework Based on RSSI and LQI

3.1 RSSI localization rule and framework

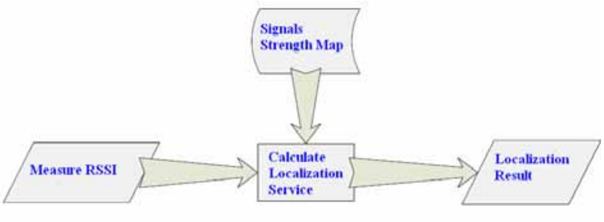

Fig. 1 System framework based on RSSI and LQ

RSSI localization rule is received three signal strength and constructed complete field distributed diagram, and also used various calculation rules such as experience law and signal attenuation model. By way of comparison and conversion the relationship between signals strength with distance, we may find out the user location by various localization algorithms. The experience law is in accordance with the match information's from receiver data and localization database. The match methods include neural network, Subspace technology in fuzzy theory, and Hidden Markov model. The signal attenuation model is in accordance with the specific relation between signals strength with distance, and employed specific model to examine for the localization information's, these models included Friis (Free Space) attenuation formula and statistics model.

3.2 RSSI signals strength value

In general we employed one bytes (0~255) represent the RSSI value via the product owner setting. In this paper, we employed CC2420 ZigBee transmission model that it provided the RSSI value by IEEE 802.15.4 regulation creation, The system must determine the RSSI value after receive eight symbols, and the range at (-60~+40) facing physical energy value. (-100~0dBm)

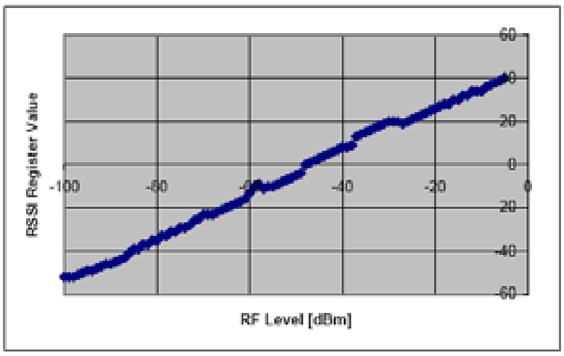

Fig. 2 A contract relation between typical RSSI with input power.

3.3 signal propagate theories computing

Receiver signals strength indication (RSSI) is a distance function between deliver power with transmitter and receive. The following formula indicated the relation is reverse ratio between RSSI with distance.

$$RSSI = -(10n\log_{10} d + A) \qquad (1)$$

n is signal propagate constant; d is between transmitter distance, and A is the receive signal strength at one meter distance between transmitter and receive.

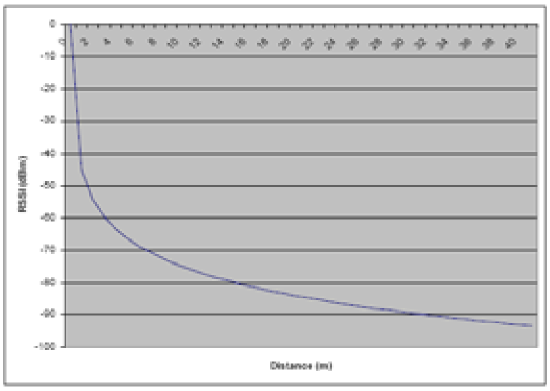

Fig. 3 The relation curve between RSSI with distance.

RSSI is often done in the intermediate frequency (IF) stage before the IF amplifier. In zero-IF systems, it is done in the base band signal chain, before the baseband amplifier. RSSI output is often a DC analog level. It can also be sampled by an internal ADC and the resulting codes available directly or via peripheral or internal processor bus.Lots of localization algorithms require a distance to estimate the position of unknown devices. One possibility to acquire a distance is measuring the received signal strength of the incoming radio signal. The idea behind RSS is that the configured transmission power at the transmitting device (P_{TX}) directly affects the receiving power at the receiving device (P_{RX}). According to Friis' free space transmission equation [6], the detected signal strength decreases quadratically with the distance to the sender.

$$P_{RX} = P_{TX} \cdot G_{TX} \cdot G_{RX} \left(\frac{\lambda}{4\pi d} \right)^2 \quad (2)$$

In above equation: the P_{RX} is "Remaining power of wave at receiver" ,P_{TX} is "Transmission power of sender", G_{TX} is "Gain of transmitter" and G_{RX} is "Gain of receiver ", λ is "Wave length " and d is Distance between sender and receiver". In embedded devices, the received signal strength is converted to a received signal strength indicator (RSSI) which is defined as ratio of the received power to the reference power (P_{Ref}). Typically, the reference power represents an absolute value of P_{Ref}=1mW.

$$RSSI = 10 \cdot \log \frac{P_{RX}}{P_{Ref}} \qquad [RSSI] = dBm \quad (3)$$

An increasing received power results a rising RSSI. Figure 1b illustrates the relation between RSSI and the received signal power. Plotting RSSI versus distance d results in a graph, which is in principle axis-symmetric to the abscissa. Thus, distance d is indirect proportional to RSSI.

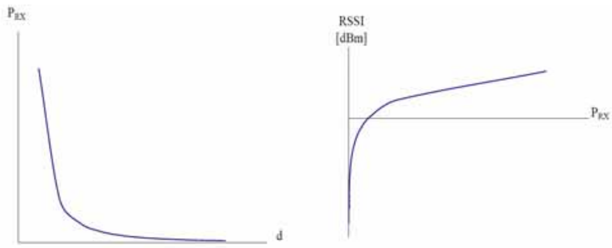

Fig. 4 (a) Received power P_{RX} versus distance to the transmitter (b) RSSI as quality identifier of the received signal power P_{RX}

The before mentioned influences during transmission of radio packets reduce the quality of RSSI extremely. Thus, localization of unknowns becomes imprecise. Another method to determine the distance is based on the link quality indicator (LQI) of the transmission. It represents a number of required retransmissions to receive one radio packet correctly at the receiver. In our laboratory, we measured the link quality indicator of the Zigbee-based devices (CC2420). The test scenario consists of two sensor nodes. One node serves as a reference device (beacon) and transmits packets continuously in a loop. The other one (unknown) logs the LQI of the incoming radio packets and forwards the LQI to the connected PC. During the measuring process, the position of the transmitting device was varied between 0 and 40m and was repeated 20 times. Each measuring process was performed with four different beacons.

The idea is to enable the large number of ZigBee-based networks with localization capabilities in a simple and cost-efficient manner, which can be realized by adding location capabilities to the sensor node silicon device itself with only marginal complexity and cost increase. By integrating such a location module tightly on-chip and basing the location estimation on one of the readily available signal indicators from the radio signal processing, such as Received Signal Strength Indicator (RSSI), the incremental size, power consumption, and complexity of the position stimation task can be kept to a minimum. Radio location is an intensive process, but using a distributed algorithm can divide the effort into manageable tasks requiring relatively modest resources at the nodes. This method can significantly reduce location-related network traffic compared to the centralized approach.

4. THE COMPUTATION OF RSSI-BASED TRILATERATION BY LOCALIZATION ENGINES

4.1 SOPC hardware design

In this paper, we employed soft-core for kernel processor by Quartus II ' s SOPC Builder and generated an processor based on Nios II core. We joined the whole circuit design and planed ACEX1K system chip, the final we finished a SOPC development platform that can control ZigBee RF communication model.

In SOPC Builder design parts included CPU, boot monitor ROM, UART, external RAM bus, external RAM,external Flash,Timer,SPI (Serial Peripheral Interface) and I/O. The CPU is NIOS II thirty-two bits version soft-core processor and its duty is process the computing and instruction of whole system, and control other circuits and components. Boot Monitor ROM is build in chip, used ACEX1K chip to implement tasks. UART be used to communication between PC with I/O and FPGA board. The responsibility of first UART is to link PC and Nios II system on board, the responsibilities of other UART is running debuggers at host PC and deliver/receive information among Stub at Nios II system. The external bus is to link the Nios II system and ACEX external memory on board; we must add a bridge between Avalon buses with external memory bus for generating Avalon three states bridge.

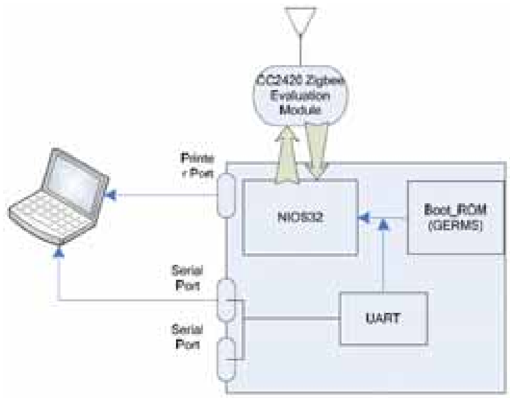

Fig. 5 The hardware framework in SOPC development platform established ZigBee wireless communication device.

4.2 SOPC software design

We proposed SOPC development platform and succeed in planning the Nios 4.0 chip, and for control and access of the CC2420 RF models by our program. The system can receive packet and set initial setting by host-PC. The software design employed C language that can be running in SOPC. The main two parts is Transmitter and Receiver. Due to the CC2420 is SOC with build in multi-states mode, we can immediate revise the operating mode via C program.

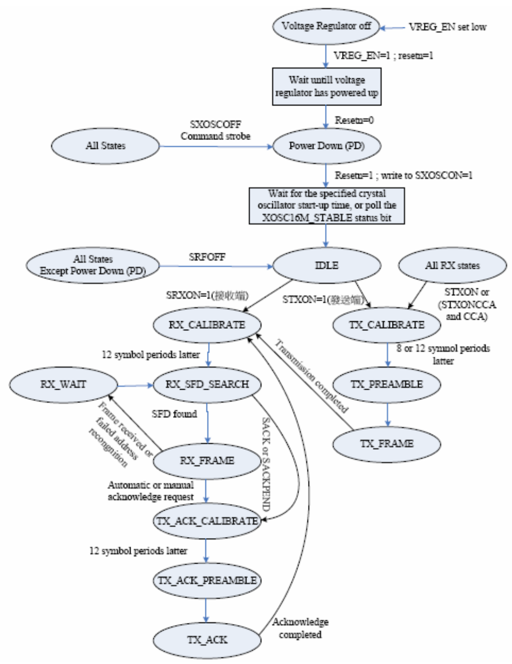

Fig. 6 The Software state control flowchart in SOPC development platform.

For the majority of ZigBee-based wireless applications, optimally designed SoC silicon devices will help downscale application system costs and design complexity without compromising the technical merits of IEEE 802.15.4/ZigBee technology. Implementing true SoC devices – that is, integrating all operational functions, such as radio transceiver, data processing unit, memory, and user application features on a single silicon die – contributes greatly to performance, cost, and time-to-market advantages. Intimate interaction between dedicated on-chip functions achieves high performance at lower power consumption and minimizes overhead. Lowest system bill of material, small footprint, few components, simpler assembly and testing, and reliable design help decrease manufacturing costs and shorten time to market. In a network, nodes with known locations are referred to as reference nodes, and nodes without a priori location knowledge that need to calculate their position are referred to as blind nodes. The ZigBee SoC device enables blind nodes to be distributed locally based on the information received from the closest reference nodes. The network traffic is limited to only the nodes within the communication range of a (blind) node, without involving a potentially far away central node. Such a distributed approach allows a large number of blind nodes to be on the same network since network traffic with a centralized approach would be prohibitively large with many blind nodes. The information required to be exchanged between the reference and blind nodes is represented by the X and Y coordinates of the reference nodes.

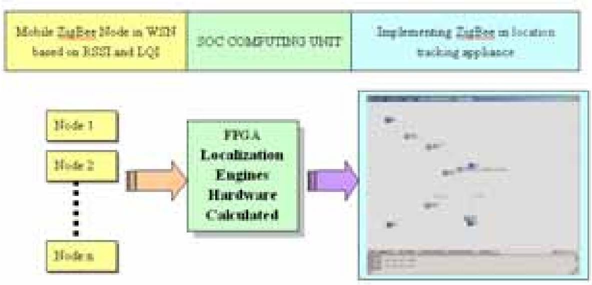

Fig. 7 The system block diagrams in describing the localization engines and appliances.

The location engine calculates its own (X,Y) coordinates based on the reference (X,Y) coordinates and the measured RSSI values of the messages received from the reference nodes. The RSSI value between two radios depends heavily on the changing environment. To compensate for this variation, the location engine collects data from 3-16 reference nodes and uses this data to calculate the position. If the location engine receives data from more than 16 nodes, it sorts the received reference node positions and uses the 16 strongest reference RSSI values.

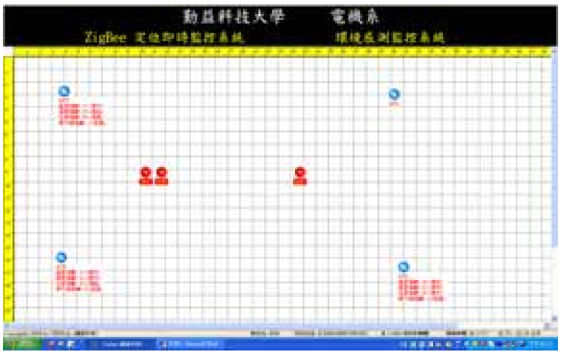

Fig. 8 The location engine calculates its own (X,Y) coordinates based on the reference (X,Y) coordinates and the measured RSSI values.

5. LOCATION ENGINE

The Location Engine is used to estimate the position of nodes in an ad-hoc wireless network. Reference nodes exist with known coordinates, typically because they are part of an installed infrastructure. Other nodes are blind nodes, whose coordinates need to be estimated. These blind nodes are often mobile and attached to assets that need to be tracked. The Location Engine implements a distributed computation algorithm that uses received signal strength indicator (RSSI) values from known reference nodes. Performing location calculations at the node level reduces network traffic and communication delays otherwise present in a centralized computation approach. The Location Engine has the following main features:

1.3 to 16 reference nodes can be used for the location estimation algorithm

2. Location estimate with readout resolution of 0.25 meters.

3. Time to estimate node location is 50 μs to 13 ms

4. Location range 64 x 64 meters

5. Runs location estimation with minimum CPU usage

To achieve the best possible accuracy one should use antennas that have near-isotropic radiation characteristics. The location error depends on signal environment, deployment pattern of reference nodes and the density of reference nodes in a given area. In general, having more reference nodes available improves the accuracy of the location estimation.

6. EXPERIMENT RESULT

The radio parameter A is defined as the absolute value of the average power in dBm received at a close-in reference distance of one meter from the transmitter, assuming an omni-directional radiation pattern. For example, if the mean received power at one meter is -40 dBm, the parameter A is specified as 40. The radio parameter n is defined as the path loss exponent that describes the rate at which the signal power decays with increasing distance from the transmitter. This decay is proportional to d^{-n} where d is the distance between transmitter and receiver. The parameters A and n can be estimated empirically by collecting RSSI data (and therefore path loss data) for which the distances between the transmitting and receiving devices are known. Figure 3 is a scatter plot of ABS(RSSI) data versus log distance in meters. A least-squares best-fit line is used to glean the specific values of A and n for the environment in which the data were measured: “A is the y-intercept of the line, and n is the slope of the line". The data in Figure 3 give A=42.4 and n=2.98 for that environment. Note that the plot in this example does not show the actual y-intercept i.e. the point on the line where x=0.

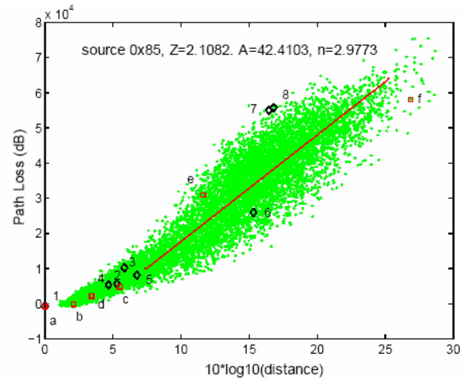

Fig. 9 Path loss vs. distance.

Compared with table1 and table 2, this study proposed that the number of the reference nodes is primary effect on precise location calculated.

TABLE 1: THIS EXPERIMENT EMPLOYED FOUR REFERENCE NODES

Position	Physical Coordinates		Estimated Coordinates		Standard	Deviation
Number	X	Y	X	Y	X	Y
1	25.3	4.2	23.4	3.2	1.9	1
2	27.2	11.7	25.2	13.2	2	1.5
3	21.8	14.8	18.3	20.3	3.5	5.5
4	29.6	17.3	23.1	10.5	6.5	6.8
5	32.2	19.3	24.3	12.4	7.9	6.9
6	40.7	21.1	32.2	13.7	8.5	7.4
7	38.1	21.3	29.2	13.5	8.9	7.8
8	43.4	22.6	34.1	14.1	9.6	8.5
9	45.3	23.3	35.1	14.4	10.2	8.9
10	48.5	24.5	36.9	14.6	11.6	9.9

TABLE 2: THIS EXPERIMENT EMPLOYED TEN REFERENCE NODES

Position	Physical Coordinates		Estimated Coordinates		Standard	Deviation
Number	X	Y	X	Y	X	Y
1	25.3	4.2	24.9	4.8	0.4	0.6
2	27.2	11.7	26.5	12.6	0.7	0.9
3	21.8	14.8	21.5	16.1	0.3	1.3
4	29.6	17.3	28.4	18.8	1.2	1.5
5	32.2	19.3	31.3	20.5	0.9	1.2
6	45.8	21.8	45.2	22.7	0.6	0.9
7	38.1	21.3	36.8	19.9	1.3	1.4
8	43.4	22.6	41.7	21.1	1.7	1.5
9	45.3	23.3	44.2	22.5	1.1	0.8
10	48.5	24.5	47.3	22.9	1.2	1.6

In the figure 10, the relations between the PRR and the link-quality parameters are given. The left picture shows the relation between the average RSSI value we measured for one link during one test and the PRR of this link. The picture on the right shows this relation for the LQI value.

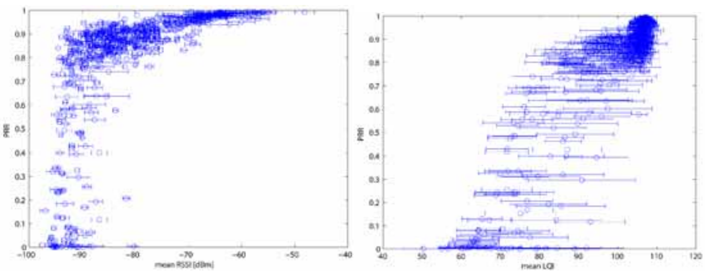

Fig. 10 The RSSI and LQI location engine performances curves

7. CONCLUSIONS

This study applies the location engine calculates to discuss the wireless sensors network location and tracking via ZigBee device based on RSSI algorithm and LQI adjustment. Employing the SOC hardware to calculate the location function, the global performances efficient is better than the conventions method at computation rate, especial is mobile ACTIVE TAG. When the location engine tends toward powerful calculated speed and its result is faster and precise rate at the location and tracking. This study employed Localization Engines would be close to the global optimal solution from wireless sensors network.

ACKNOWLEDGMENT

The authors would like to thank the National Chin-Yi University of Technology, Taiwan for financially supporting this research.

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